Noble Gas Isotope Studies of Geothermal Systems

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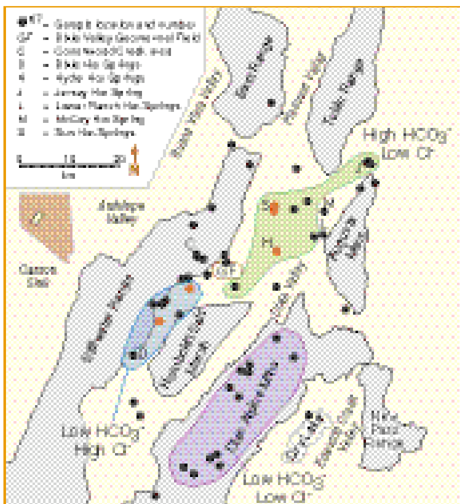
RESEARCH OBJECTIVES

This project develops isotope tracers for identifying fluid and heat sources and studying fluid processes in geothermal systems. Recently, we have concentrated on identifying geochemical and/or isotopic signals that can be used to locate geothermal systems in regions lacking recent volcanic activity and surface manifestations of deep hot fluids.

APPROACH

Fluids within the earth's crust contain noble gases (helium [He], neon [Ne], argon [Ar], krypton [Kr], and xenon [Xe]) from a variety of sources, each characterized by a unique composition, and therefore contributions from different sources can be easily identified. For instance, geothermal fluids that acquire heat from active magma systems are strongly enriched in ^{3}He, with ^{3}He/^{4}He ratios up to 9 times the ratio in air (R/Ra ~ 9); those that acquire heat from the natural thermal gradient are depleted in ^{3}He (R/Ra ~ 0.02). This vast difference provides a sensitive quantitative measure of fluid and heat source driving a geothermal system and fluid mixing within the system.



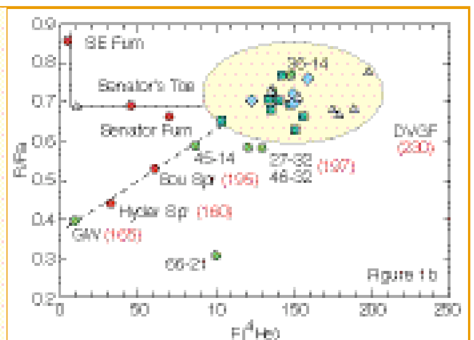


Figure 1a: Map showing the location of Dixie Valley wells, springs, fumaroles, and the Dixie Valley Geothermal Field. Features identified by letters (see Legend) were sampled for noble gas isotope analyses.

Figure 1b: Helium isotopic compositions (R/Ra) for the Dixie Valley samples are plotted as a function of the 4He/36Ar ratio (normalized to the ratio in air). The F(4He) values reflect the degree of helium enrichment relative to that expected for young meteoric waters [F(4He)~ 0.2]. The composition of Dixie Valley geothermal production wells plot within the ellipse. The dotted line emanating from the ellipse portrays the trajectory expected for either boiling (e.g., Senator's Toe and Fumarole) or air contamination (SE Fumarole). The dashed line depicts two fluids mixing. Numbers in parentheses are calculated chemical geothermometer temperatures.

ACCOMPLISHMENTS

The Dixie Valley Geothermal Field, Nevada, is considered a classic nonmagmatic geothermal system that acquires heat by deep fluid circulation. Similar systems occur throughout the Basin and Range Province of northern Nevada. Fluids sampled throughout Dixie Valley (Figure 1a) have a range in helium isotopic compositions (~0.3–0.8 Ra). The highest values (0.7–0.8 Ra), found in fluids produced from the Dixie Valley Geothermal Field, suggest that the natural thermal gradient provides ~85–90% of the reservoir heat. Co-variations between He isotopic composition and abundances (Figure 1b) require mixing of two fluids, and also require that all of the sampled features (except Well 66-21) contain a fluid component indistinguishable from that produced from the geothermal field.

SIGNIFICANCE OF FINDINGS

The observation of a common deep fluid throughout Dixie Valley suggests the presence of a larger exploitable geothermal resource than presently under production. This study also demonstrates the utility of noble gas isotopes for finding and evaluating the extent of hidden geothermal systems.

RELATED PUBLICATIONS

Kennedy, B.M., M.C. van Soest, and S. Johnson, Helium isotopes in Dixie Valley wells, springs, and fumaroles: Heat and fluid sources; regional trends. Geothermics, 2003 (submitted).

Kennedy, B.M., T.P. Fischer, and D.L. Shuster, Heat and helium in geothermal systems. Proceedings, 25th Workshop on Geothermal Reservoir Engineering, Stanford Geothermal Program Report SGP-TR-165, pp. 167–173, 2000.

ACKNOWLEDGMENTS

This work was supported by the Assistant Secretary for Energy Efficiency and Renewable Energy, Office of Technology Development, Office of Geothermal Technologies, of the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.